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Tactical Communications Research and Development Requirements from Signal and Behavioral Science Perspectives

Dorothy L. Finley
U.S. Army Research Institute

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14. ABSTRACT *(Maximum 200 words)*:

Requirements are described for research on the effects of signal realities on Army warfighters to minimize their frequency of occurrence and adverse impacts. "Signal realities" are defined as degradation of electronic communications and automation capabilities as can occur during tactical operations under actual dynamic battlefield conditions. This report analyzes the realities and consequences of battlefield communications degradation; Signal Branch roles in combat; warfighter tendencies to overlook signal realities during operations and exclude realistic communications problems from training; and behavioral science literature on this topic. Based on this information, research goals are specified to identify and clarify effects of degraded signal on battle processes and outcomes; how procedures might be modified to avoid, or adjusted to overcome, these effects; interdependent relationships between signal and warfighter tasks when conducting collective missions, and those tasks best accomplished jointly; and how to improve, through training, battlefield tactical operations supported by signal equipment capabilities. Research areas supporting these goals are then discussed. These include specifying the impacts of communications capability on battle processes and outcomes; identifying training requirements; answering related training research questions and concerns; exploring possible changes in soldier functions, duties, and organization; and developing tools to aid digital battlefield performance.

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FOREWORD

Army XXI, the 21st century force, is expected to be digitally equipped. Advantages from digitization include increases in the speed with which data can be sent and received, and in the amount of information available to soldiers and leaders.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is committed to determining how to enable soldiers to take full advantage of these new digital capabilities. This report describes key communications research requirements prerequisite to preparing warfighters to anticipate, and avoid or cope with realistic degradation of electronically provided information. It provides analyses of the tactical communications problem as well as defines areas that require behavioral science research. The problem analysis draws on information from many sources, including such agencies as the Signal Center, Armor Center, U.S. Army Simulation, Training, and Instrumentation Command, and Army Research Laboratory's Human Research and Engineering Directorate. Also critical to an understanding of this area of research are findings from the Army's Advanced Warfighting Experiments.

This ARI effort was performed under Science and Technology Objective IV.0.6, Research Task 2228, FASTTRAIN, Force XXI Training Methods and Strategies. It provides input to the design of research programs to address training and other soldier and/or leader issues related to tactical communications degradation.

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TACTICAL COMMUNICATIONS RESEARCH AND DEVELOPMENT REQUIREMENTS FROM SIGNAL AND BEHAVIORAL SCIENCE PERSPECTIVES

EXECUTIVE SUMMARY

Research Requirement:

The usual environment constructed for military analysis, testing, training, and other activities is one where perfect communications capability and quality is the rule insofar as possible; whether or not this is an accurate depiction of an actual operating environment. In contrast, the realities of the tactical battlefield (e.g., changes in terrain, actions by the opposing force) are such that successful transmission and reception of electronic voice, data, and graphics communications—not to mention the completeness and validity thereof—are never certainties. Battlefield digitization includes the addition of enhanced communication capabilities. Realization of the full benefits of digitization, as well as those of current signal equipment, requires development of appropriate changes in operating procedures, processes, and training systems to accommodate the reality of intermittent communications degradation. Research is needed to identify and specify the required changes in each of these.

Procedure:

Two approaches were taken. One was to analyze military electronic communications from several aspects. These aspects included the roles and responsibilities of the U.S. Army Signal Branch; benefits to be gained from digitizing the battlefield; pitfalls in ignoring the realities of communications degradation on the battlefield; and transparencies regarding and exclusions of realistic variations in communications capability in training and elsewhere (e.g., modeling). The other approach was to review research literature and military documentation. The context, in each case, was planning, preparing, and executing battlefield maneuver and engagement operations. The focus was not on possessing very technical electronics expertise nor on equipment operation procedures. The focus was, instead, on tactical use of electronic signal equipment for communications by warfighters and support thereof by signal soldiers.

Findings:

Evidence is presented to support two assertions: (1) Electronic communications degradation <u>can</u> have negative effects on battlefield performance, and (2) Soldiers with appropriate training <u>can</u> minimize these effects. Research goals and

requirements were identified to : (1) determine how to minimize adverse communications degradation effects on battle outcomes through actions by the soldiers, (2) determine how to optimize interdependent signal and warfighter tasks and task relationships, and (3) identify training requirements and effective strategies.

Utilization of Findings:

This report can serve as a vehicle for discussions and provide inputs to outlines for research programs directed toward better realizing advantages offered by a digitally equipped Army XXI and the capabilities of the current Army as well. Potential discussants for possible research efforts include at least: U.S. Army (USA) Signal Center; USA Armor Center; USA Simulation, Training, and Instrumentation Command; U.S. Army Research Laboratory Human Research and Engineering Directorate; Department of the Army (DA) Office of the Deputy Staff for Personnel; DA Director of Information Systems for Command, Control, Communications, and Computers; U.S. Army Digitization Office; USA Training and Doctrine Command (TRADOC); TRADOC System Manager Force XXI; and U.S. Army Research Institute for the Behavioral and Social Sciences.

TACTICAL COMMUNICATIONS RESEARCH AND DEVELOPMENT REQUIREMENTS FROM SIGNAL AND BEHAVIORAL SCIENCE PERSPECTIVES

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TACTICAL COMMUNICATIONS RESEARCH AND DEVELOPMENT REQUIREMENTS FROM SIGNAL AND BEHAVIORAL SCIENCE PERSPECTIVES

"Reliable communications are central both to battle command and to control. General Omar Bradley once said, 'Congress can make a general, but only communications can make him a commander.'"
(U.S. Army, 1993, p. 2-15)

"The nature of warfare has changed dramatically. The combatant that wins the information war prevails in war."
(MG Gray, 1993)

Introduction

The purpose of this report is to describe requirements for behavioral research concerning signal realities - that is, variations in electronic communications (C3) and automation (C4) quality - that occur as a part of tactical operations. The focus is on <u>tactical</u> signal knowledge and skills needed by both warfighters and signal soldiers during operations on a dynamic battlefield. The focus is not on extensive electronics expertise as possessed by signal soldiers nor is it on equipment operation procedures in and of themselves; rather it is on the tactical use of electronic signal equipment for communications.

Responsibilities of the Army's Signal Branch include: design and development of signal equipment items (e.g., radios, satellites, computers); situating and maintaining these items on battlefields; and managing the resulting electronic assets (e.g., allocating frequencies, establishing and modifying networks). A major Signal focus is on optimizing the probability of successful transmissions and receptions from an engineering standpoint. The behavioral issue addressed here is how to best prepare soldiers, who are not signal soldiers, to use these electronic capabilities in tactical situations. The questions are how to train or otherwise prepare these soldiers to anticipate and/or avoid communications problems, and then how to deal with those which are unavoidable.

Users of signal equipment who are not signal soldiers are called "general purpose users" (GPUs) by the Signal community. "GPU" is becoming a job descriptor for increasing numbers of soldiers whose training and responsibilities are not in signal but in other areas (e.g., infantry, artillery). The GPUs being addressed here are the warfighters. Warfighters in higher echelon command and staff positions are able to draw assistance from signal personnel more directly. Warfighters in lower echelons, however, do not have these personnel immediately available. Signal soldiers in battle staff positions generally first appear at the battalion echelon level.

The research requirements to be described here will be based on these premises:

1. The realities of the battlefield are such that successful transmission and reception of communications - not to mention the completeness and validity thereof - are never certainties. Signal equipment reliability *per se* is not the issue here. Rather, it is that signal capabilities can more often be limited or degraded by a number of other factors. Examples of these other factors include: distance, terrain obstructions to line-of-sight (LOS), meteorological conditions, soil composition, baud rate, band width, power, and hostile actions by the Opposing Force (OPFOR).

2. "Reliable C3 and C4" (i.e., communications and computers) is stated as a requirement in Field Manual (FM) 100-5 (U.S. Army, 1993). For reasons given in the first premise, "reliable C3 and C4" - in the sense of consistently perfect performance, quality, and validity - can never be guaranteed on a dynamic battlefield, with or without hostile actions by the OPFOR. Some variations in quality and validity can, however, be predicted or anticipated (e.g., the likelihood of terrain obstructions) or viewed as possibilities (e.g., OPFOR jamming of radio frequencies, greater than expected distances between those troops needing to communicate). If plans are developed, preparations made, and executions performed in recognition of potential problems and with definition of appropriate contingency actions, then whatever level of C3 and C4 reliability is feasible will be achieved.

3. Given the first two premises, individual and collective knowledge and skills regarding signal realities on the battlefield are needed for effective combat operations.

4. Realistic communication and automation degradation, as would occur in actual combat, is generally avoided in training (Finley, 1997; Mueller, 1991). This training deficiency will become more critical as we move toward the Force XXI digitized battlefield of the future (Parry, et al., 1996; Rosenberger, 1996).

Goals for the proposed research are to identify and clarify:

1. Effects of degraded signal on battle processes and outcomes, and how procedures might be modified to avoid, or adjusted to overcome, these effects;

2. Interdependent relationships between signal and warfighter tasks when conducting collective missions, and those tasks best accomplished jointly; and

3. How to improve, through training, battlefield tactical operations supported by signal equipment capabilities.

This report will first outline Signal Branch roles in combat, and the realities and consequences of battlefield communications degradation. It will be suggested that signal realities tend, too often, to be overlooked during operations and that one causative factor may be the common avoidance of communications problems while training. The above goals will then be restated as research hypotheses along with a presentation of what is currently known from the behavioral science research literature. The final section will outline requirements for research in tactical communications training and other related issues.

Underlying these presentations is the contention that advancements in C3 and C4 technology - if accompanied by appropriate behavioral research and implementation of findings - will indeed result in a reduced "fog of war" and increased situational awareness. This should, in turn, lead to increased combat effectiveness (Parry, et al., 1996; Rosenberger, 1996). This contention is based on the proposition that more and better information will aid decision making processes. "Information" is defined here as those data, transformed as required, which provide necessary, sufficient, and timely knowledge. Data not meeting these criteria, nor transformed appropriately, do not effectively serve the needs of C1 and C2.

The criteria of necessary, sufficient, and timely are long standing ones. The point here is that soldiers who have not been trained to expect communication imperfections and have not developed tactical skills for dealing with them may have inadequate or flawed cognitive processes for transforming incoming data. Dependence on the benefits of C3 and C4 advancements, if combined with unrealistic expectations of perfect signal quality at all times, could lead to an increased "fog of war" on the part of C1 and C2 when degradation occurs. This could result in a decrease in combat effectiveness rather than the anticipated increase.

Communications Considerations

The terms "communications" and "signal" are both used in this report. They are generally used synonymously and refer to voice, data, and graphic messages which are sent and received via electronic communications and computer equipment. "Communications" is certainly the more everyday term. The term "signal," however, will be used frequently to reinforce the concepts that variations in electronic message quality (including whether or not received at all) are to be expected; and that, by nature, signal quality variations are not capricious.

Signal Branch's Mission, Role, and Responsibilities

LTG Horner (1991), in describing signal as a part of his experience in war, stated: "Having the best personnel, equipment

and plans are meaningless if you cannot talk to anyone or have a functioning system for command and control" (p. 17). FM 24-1, Signal Support in the AirLand Battle (U.S. Army, 1990), expands on LTG Horner's statement by defining the Signal mission as:

> Signal support is the implementation of the Information Mission Area (IMA) at the operational through tactical levels of war. It is also the collective, integrated, and synchronized use of information systems to support warfighting capabilities across the operational continuum ... Signal support's primary mission is to support the commander. (p. 1-1)

From a historical perspective, the overall role of the Signal Corps in the modern Army is portrayed as:

> The U.S. Army is now undergoing the most dramatic peacetime force modernization in its long history, and the Signal Corps is in the forefront ... Every weapon system, command control system and functional area is dependent on electronics and the transmission, switching, and control facilities/services largely provided by the Signal Corps (Office Chief of Signal, 1991, p. 23).

The Army's Signal Branch has to meet many responsibilities in serving these roles and missions at the tactical level. Among these are: design and development of signal equipment items (e.g., radios, satellites, computers); situating and maintaining these items on battlefields; and managing the resulting electronic assets (e.g., allocating frequencies, establishing and modifying networks). A major focus is on optimizing the probability of successful transmissions and receptions from an engineering standpoint.

Benefits from Digitizing the Battlefield

Rapid and well advertised advances are being made in communications and computer technology (e.g., very high speed circuits, packet switching, asynchronous transfer, pseudo satellites). These advances are resulting in increased capabilities, speed, and ease of use. The U.S. Army is making a major push, through the process of Force XXI, to take advantage of these advances by "digitizing the battlefield" ("Army Building Digital Foundation for Future", 1994; Conway, 1995; Director of Information Systems for Command, Control, Communications, and Computers, 1993; Rosenberger, 1996). Army XXI, the product being created by this and several other Force XXI efforts, is the Army's vision for the 21st century.

A series of Advanced Warfighting Experiments (AWEs) are being conducted to explore several Force XXI initiatives, including that of digitizing the battlefield. One AWE goal is to identify gains that can be made by exploiting digital electronics technology, especially new advances appearing suitable for

military operations. Gains are especially sought in lethality, survivability, and operating tempo. One of the 1995 AWEs, called Focused Dispatch, was conducted to test the effects of digitization on a mounted maneuver battalion task force. It was anticipated that, among other things, logistics support would demonstrate major improvements as a result of digitization. That, indeed, was found to be the case. The extent to which supplies of the appropriate types and amounts arrived dependably, when and where they were needed, was viewed as truly remarkable. Parry et al. (1996, page 6-21) stated that "The asset awareness of the Combat Trains Command Post (CTCP) ... allowed an unprecedented level of management of resources."

Realities and Consequences of Signal Degradation on the Battlefield

The realities of the battlefield are such that successful transmission and reception of communications - not to mention the completeness and validity thereof - are never certainties. Highly probable - yes; certain - no. There has never been a time, and probably never will be, when electronic communications will be - under all conditions - 100% perfect. This is true even if the equipment is totally reliable and the equipment operating procedures, in and of themselves, are performed perfectly. Communications and digital operations can be degraded by a number of factors other than the relatively rare equipment failure, or such operating errors as omitting an essential procedural step or transmitting a message over the wrong network.

Examples of the degrading factors of concern here include terrain features, distance, meteorological conditions, electronic interference, and enemy actions. Examples of the effects of these factors include missing, delayed, or incorrect data; no data being received at all; and inability to hear or decipher voice messages. Often, the occurrence of these factors can at least be anticipated, and it may even be possible to predict such specifics as time and place. This being the case, the hypothesis is that soldiers can, by their own actions, be better able to avoid electronic communications degradation and, if encountered, less vulnerable to its effects. These actions include performing appropriate planning, preparation, and execution tasks. However, without realistic expectations and preparation, communications degradation can be far more serious than being a mere hindrance; and the potential benefits of battlefield digitization cannot be fully realized.

Vulnerability to degradation can be created when soldiers plan missions without checking assumptions that their signal capabilities will work, and work equally well, for all courses of action (COAs) under consideration. Terrain obstructions may, for example, make communications more difficult with some approach paths than others. For other reasons that may or may not be related to terrain features, some approach paths may be much more vulnerable to OPFOR surveillance or destructive action. If these

possibilities are not identified and evaluated first, and then anticipated or avoided, then signal degradation occurring under the selected COA can impact negatively on the likelihood of mission success.

Brigade Headquarters is one echelon where developing COAs with the foregoing omissions is a definite possibility. This is due to the limited amount of staff signal support usually available. This support may increase, however, given such observations from the battalion-level AWE Focus Dispatch as: "There is no evidence that staff organization should change; however, the role of the Signal Officer will expand..."; "What was clear ... was the impact of the [digitization] systems on the role and responsibilities of the Signal Officer" (Parry et al., 1996, pages I-7 and 1-8).

At an Armor company level, a lower echelon, there is no staff signal support. Vulnerability to degradation can arise at this level due to failure to analyze COAs and the associated METT-T for ability to communicate as they apply specifically to their part of the mission. Analyses by company personnel are needed regarding, at least, their ability to communicate throughout the mission: (1) within their own company and (2) between their company and such other battlefield elements as the tactical operations center (TOC). Dealing with these requirements can be considered a part of company-level and lower COA planning and execution where, again, some knowledge and skills in tactical signal realities are needed on the part of GPU warfighters. Although the needs and abilities to deal with signal realities at these lower echelons are simpler, it is also true that, as noted, signal soldiers are not generally available to directly assist these warfighters.

An example of vulnerability limited to equipment operating status, but potentially critical nonetheless, is that which can be created when soldiers are accustomed to using only one communications asset (e.g., a particular radio) as a matter of normal routine. If the asset has always worked before (albeit under benign circumstances), it is sometimes assumed that it will work just as well during the upcoming mission. This assumption can become a liability if the asset does not work well, or at all, during a critical point in the mission and the soldiers do not remember what contingency actions can be taken and how to accomplish them. Signal soldiers have described observations to me of many such incidences taking place during tactical operations. Similar anecdotal evidence has been cited by training observers/controllers with comments that, if many of the responses observed during major training exercises were to take place during actual combat, the consequences could be very serious.

Logistics successes were described above for AWE Focused Dispatch. Reynolds (1996), however, raises the possibility of vulnerability and accompanying support failures if logisticians

become too focused on computerized and electronically connected logistics systems. Reynolds is concerned that "Computers ... are sensitive, vulnerable machines, easily susceptible to incidental and battlefield damage ... the whims of nature can disable an entire system ... an advanced enemy may have the ability to embed viruses in a network." (1996, page 33) Reynolds points to the training issue, contending that skills must continue to be maintained in exercising the principals of support and alternative means of implementing them; as well as developing skills for operating the new computerized and electronic network-supported logistics systems.

Signal Reality Transparencies in Training

It has just been suggested that there are potential costs for not anticipating and preparing for potential communications degradation on the battlefield, and not making COA choices to minimize this to the extent reasonable. Given these costs, one would expect that realistic communications - that is, variations in communications quality as would normally occur on the battlefield due to distance, obstructions, jamming and destruction by an OPFOR, etc. - to be included as a part of tactical combat training. Perhaps they should be, but they are not (Finley, 1997; Mueller, 1991). (Incidentally, neither are realistic signal variations included in most simulation models used for analysis; nor in the conditions set up for testing many new operational and materiel concepts.) In fact, with regard to training - be it conducted using constructive, virtual, or live simulations - signal realities are often excluded or avoided purposefully. Mueller (1991) sums up the situation by noting that "The current training environment found in the Army expects (and has been conditioned to expect) uninterrupted communication support" (p. 89).

Even when training in live environments, the quality and capability of communications is always made, often artificially so, to be as close to 100% perfect as possible. In major live training exercises, for example, the communications assets (equipment, relay nodes, frequencies, etc.) are assigned, installed, set up, and checked out well before the exercise begins. (This, of course, is contrary to the often hasty setups made during actual combat.) This is done in accordance with the anticipated training mission and terrain movement patterns in such a way as to ensure continuous and high quality communications support. Where the same training area is used repetitively over time, particularly smaller areas at training installations, any potential problems are known at the outset and movement patterns are often fairly standardized ones which avoid communications problems. OPFOR hostile actions are usually limited if played at all. In summary, situations that would train skills in avoiding and handling communications degradation problems are generally avoided or excluded.

Should Signal Degradation Realities Continue to be Made Transparent?

Common tendencies, then, are to not actively consider the possibility of adversive signal realities during operations nor to include them during training. The failure to encounter realistic signal degradation during training may be one of the causes of failure to actively address the possibilities during operations. Both of these tendencies may stem from the view - held by many trainers and signal soldiers - that the signal support role is best implemented by making the support as transparent as possible to warfighters and others. Those holding this view often voice the opinion that warfighters, for example, should not be distracted from learning and performing their primary responsibilities. This may have been an appropriate opinion in the past, especially given the limited amount of training time and resources, and the enormous amount to be learned regarding these "primary responsibilities." However, the picture has changed somewhat, given electronic technology advances and its applications in digitizing the Army XXI battlefield. The growing numbers of signal asset GPUs - which group increasingly includes warfighters - with major responsibilities dependent on signal capabilities, and the real world variations thereof, may have changed the appropriateness of this perspective. I suggest that it is no longer wise for signal asset GPUs to not fully understand the importance of signal realities during planning, not actively pursue full coordination with assigned signal personnel, and not know how to deal with signal realities during preparation and execution as appropriate within one's own battlespace.

Research Background

Research Goals, Underlying Contentions, and Past Research

In the introduction, three research goals were presented for the issue of tactical signal realities on the battlefield. These can be summarized as:

1. Determine how to minimize adverse signal degradation effects on battle outcomes through actions by the soldiers;

2. Determine how to optimize interdependent signal and warfighter tasks and task relationships; and

3. Identify the necessary training requirements and best training strategies.

Two contentions underlying these three goals are that:

1. The capabilities of command, control, communications, and computers (labeled C1, C2, C3, and C4 in this report) are interdependent. C1, C2, C3, and C4 each play a role in defining each other's capabilities. For example, command can create

conditions that modify or enable communication capabilities; and computers can enable and/or accomplish some control actions.

2. Using communication and computer assets wisely and well under dynamic tactical conditions will make a difference.

Some past research efforts have been located which appear to provide support for these contentions and/or provide starting points for investigations. Each will be discussed in turn. They are:

1. Command and control (i.e., C1 and C2) definitions and possibilities for expanding these definitions to include signal (i.e., C3 and C4);

2. Army Command and Control Evaluation System (ACCES) for evaluating command and control processes;

3. A system information processing model for evaluating command and control effects; and

4. Empirical evidence of relationships between communications capability and combat soldier performance.

Command and Control (i.e., C1 and C2) Definitions, and Possibilities for Expanding These Definitions to Include Signal (i.e., C3 and C4)

Crumley and Sherman (1990), in reviewing models and theories of command and control, found many variations in how command and control was defined. The variations were primarily a result of the orientation of the definers. Definers ranged from computer technologists to behaviorists to implementers; the latter concerned with, for example, command post staffing and design. Crumley and Sherman felt that the one provided by the Joint Chiefs of Staff (Department of Defense, 1987) was a particularly important one in that this definition "implies that command and control is primarily a management function." (p.2) They went on to say, "Unfortunately the management definition is rarely used in the reviewed literature." (p. 3) They commend Finley, Muckler, Gainer, and Roe (1974) for providing such a definition in their research: "Command and control is the management component of any system." (p. 15) This is the definition that will be used in this report. In 1975, Finley, Muckler, Gainer, and Obermayer expanded this definition with:

> C&C [C1 and C2] is a subsystem. For some purposes, it may be useful to consider C&C as an isolated entity. For example, when problems have been identified in the C&C element, those problems may be examined solely within the element itself. But, the use of the phrase "command and control system" is a conventional convenience. What is ultimately of interest is what the C&C component does in

relation to all other components of the total system [underlines added]. (p. 15)

The foregoing says, in essence, that whether C1 and C2 are best dealt with as the management element of a system or as an entity in and of itself depends on one's purpose. It is contended here that signal, C3 and C4, can also be defined to be an element in a larger context or can, instead, be considered separately. The choice would, again, depend on one's purpose. Figure 1 presents a depiction of some alternative delineations of the scope and content of the problem area to be analyzed, researched, developed, tested, evaluated, or trained. Which of the elements C1, C2, C3, C4, or the system itself are included in the problem definition differs in each of the blocks displayed in Figure 1. For examples of systems, consider a mounted maneuver brigade, a transportation system, or an air defense system. The blocks to the right in Figure 1 all include aspects of the system (e.g., operational through-put processes and production rates) as an integral part of examining the problem. In the lower right hand block in Figure 1, the problem delineation would include: C1 and C2 as the managing components of the system; C3 and C4 acting as support components implementing C1 and C2; and the rest of the total system (e.g., a mounted maneuver brigade) with its mission, objectives, operations, etc.

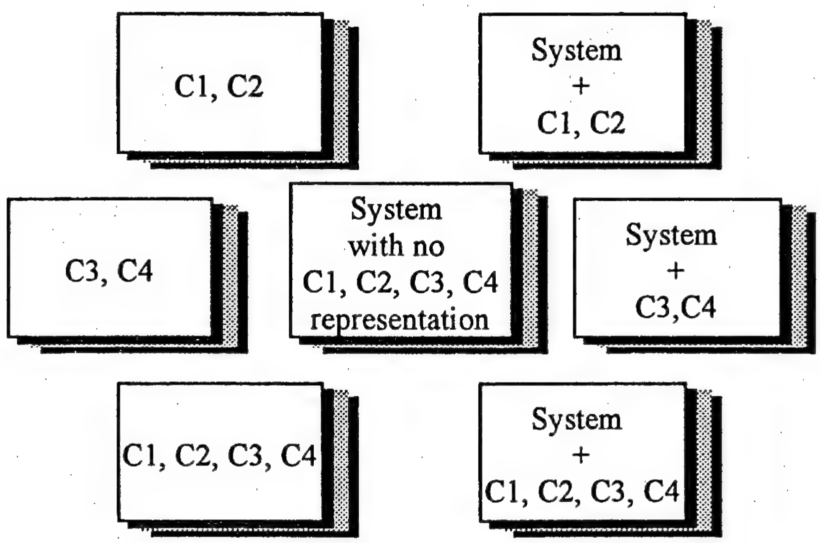

Figure 1. Alternative delineations of the scope and content of a problem area to be addressed.

Each of the problem delineations in Figure 1 allow for consideration of a different set of variables. Each view serves some purposes better than others. The smaller the view (e.g., the left hand box containing C3, C4), the greater the focus on more narrowly and specifically defined variables, and the greater

depth to which operation of a specific component (e.g., C4) can be examined. This kind of view is often appropriate at some stages of developmental testing, for example, the early debugging runs of parts of a software program; or the early stages of training where, for example, students are learning basic operating procedures for individual equipment. The larger the view, the greater the ability to test or train interactions between components (e.g., C1, C2, and C3), and the greater the ability to learn and assess the outcomes of these interactions. The latter becomes particularly appropriate, for example, when considering brigade staff training where learning with whom to interact, about what, is an important objective (Harrison and Bartkoski, 1996; Quinkert, 1996a, 1996b).

The next two research efforts each exemplify use of a different selection from the alternative views described in Figure 1. The first focuses primarily on C1 and C2 processes *per se* (a left hand block in Figure 1) but does incorporate some measures related to C3. The second describes a modeling approach to simulating a system which allows play of various combinations of C1 and C2 as they affect and effect system operations and outcomes. Potentially, C3 and C4 components could also be played within this approach. This latter simulation provides a means for assessing system operations and performance, and the effects of varying levels of C1 - C4 capability on these operations and performance.

Army Command and Control Evaluation System (ACCES) for Evaluating Command and Control Processes

ACCES has been under development since 1986 (Halpin, 1996; Hayes, Layton, and Ross, 1995). Its focus is on processes executed by headquarters staff at Army brigade, division, and corps levels during training exercises or during operational tests of, for example, new equipment where the effects of the equipment on command staff performance are important considerations. Its purpose is to provide diagnostic and evaluative staff performance information. The intent is to provide information that is useful for providing training feedback; and for comparing headquarters staffs when performing under different conditions. The different "conditions" might be, for example, different staff organizational configurations, the addition of more automation, doctrinal changes, or a change in a subsystem (e.g., fire support) of the overall system. In each case, performances of staff processes comprise the dependent variables.

Realistic signal, e.g., effects of weather on voice quality, or destruction of C3/C4 nodes disrupting transmission and receipt of communications, has not been played as a part of any training or testing exercises in which ACCES has been used thus far. ACCES has not been designed, up to this point, to attend to staff actions that would include attention to planning, management, and contingency actions with regard to signal. However, ACCES

currently includes some metrics that would be affected if the effects of signal realism variables were of concern. Examples include punctuality of incoming and outgoing information. ACCES could possibly be expanded to also include metrics for assessing battle staff activities with regard to signal realities. An example might be scoring the extent to which staff members consider adverse signal realities when developing and comparing alternative COAs.

A System Information Processing Model for Analyzing and Evaluating Command and Control Effects

Obermayer developed the Command and Control Analysis Model (Finley, Muckler, Gainer, and Obermayer, 1975; Obermayer, 1975). The modeling concept is to use computer simulation languages to create an operating model of the system to be analyzed. The system's operations are described in terms of flows, or pathways (e.g., data and information flows, traffic flows), within which processes and events take place. The system's pathways, processes, events, and surrounding environment are described as needed to allow them to be modified, enhanced, degraded, or eliminated as would be appropriate as a result of C1 and C2 action or inaction.

A demonstration of how to implement the Command and Control Analysis Model was developed. This demonstration produced statistical records that could be used to determine system performance and effectiveness, and then to analyze the changes in same resulting from C1 and C2 changes. The simulation language used for the demonstration was the General Purpose Systems Simulator Language (GPSS) (International Business Machines Corporation, 1965a, 1965b). The system modeled was an air traffic control system as found aboard Navy carriers. The system process that was modeled was execution of aircraft recovery operations.

The power of this approach is that it allows the analyst to vary events and processes "...to reflect the effects of training, changed standards, ..., etc.; that is, the effects of changes in factors that can be modified by command action." (Obermayer, 1975, p. 28) Put another way, Obermayer's approach was to develop a system simulation model that "...reflects the effects of C&C [C1 and C2] strategies and tactics on the states and activities of system components and the consequent effects on their performances and effectiveness." (p. viii) The model defines command and control as any manned system's management element and emphasizes its responsibility for establishing and directing "...system mechanisms for the purposes of C&C information acquisition and utilization" (p. vii).

Extrapolating from the foregoing concepts, the system simulation computer language approach might also be used to analyze and, perhaps, evaluate performance and effectiveness resulting from the combination of signal with C1 and C3

variables. That is, computer simulations of systems might be created which respond to not only the effects of signal realities, and of command and control decisions - but also to interdependencies between the capabilities of command, control, communications, and computers. Earlier in this section, it was contended that these interdependencies constitute underpinnings to our research goals.

Perhaps changes in C3 and C4 capability could be described and simulated so as to affect system operations in two ways: (1) By acting as an independent factor which directly affects C1 and C2 (e.g., through the provision or withholding of timely and accurate information); or (2) By acting as a dependent factor, which is modified, enhanced, or degraded by the decisions of C1 and C2. In the first case, C1 and C2 decisions would be influenced by the timeliness and quality of information provided by C3 and C4 assets. Timeliness and quality of the information could vary as a function of which COAs were selected, signal network architectures, OPFOR action, etc. In effect, the computer simulation of system operations would change to reflect C1 and C2 resulting from signal capabilities or lack thereof.

To represent the second case, the capability levels of C3 and C4 assets might be varied to reflect the effects of C1 and C2 decisions regarding C3 and C4. For example, in selecting COAs, the COAs could differ in terms of terrain obstructions, OPFOR actions, or requirements to relocate or replace signal assets.

Taking this a step further and towards one of the issues addressed by Obermayer, differences in C1 and C2 decisions regarding selection of COAs might, in turn, be used to represent hypothesized effects of training appropriate for a commander with regard to C3 and C4. Along another tack, one relevant to Halpin's interests, the Command and Control Analysis Model might serve as an analytical means (vice the empirical ACCES) for evaluating new C4 equipment or doctrine.

<u>Empirical Evidence of Relationships between Degree of Communications Degradation and Combat Soldier Performance</u>

There is a vast amount of research literature on human communication behaviors in and of themselves. Communications content, for example, has been shown to vary as a function of such things as experience, lexicons, stress, personalities, and alternative message routing and dependency relationships between people. In contrast, there are practically no reported research studies that have examined skills in managing real world communication channel degradation and how these skills might best be trained. I could find nothing, for example, on the effects of enhancing, through training, human C1/C2 <--> C3/C4 interactions in planning for, managing, and dealing with communications capability variations when using electronic signal equipment in a tactical setting.

I did, however, find some research studies reporting on the effects of different levels of communications quality on mission performance and outcome. This progress has been made through efforts by Schmidt-Nielsen, Kallman, & Meijer, 1990; Whitaker, 1991; Whitaker & Peters, 1990, 1993; Whitaker, Peters, & Garinther, 1989; Whitaker, Peters, & Mitchell, 1992. Whitaker and Peters (1993) stated:

> In literature reviews completed in 1989, we found that, despite the extensive coverage of speech intelligibility per se (e.g., Miller, Heise, and Lichten, 1951; Kamm, Dirks, and Bell, 1985; Sanders and McCormick, 1987), little had been reported of the impact of intelligibility on task performance. Therefore, we began the present program of research. (p. 630)

Whitaker and Peters (1993) describe the goal of their program as: "...to quantify the effect of speech intelligibility on performance of various types of communication-intensive tasks" (p. 631). Their research to date (see above citations) reports on navigation and gunnery tasks performed as a part of combat missions. The tasks were performed by individual Infantry Fighting Vehicle and Armor tank crews, and by Armor tank platoons. The data were collected on crews performing in Bradley Conduct of Fire Trainers and M1A2 (Abrams) tank simulators, both in the Simulation Network (SIMNET) facility located at U.S. Armor Center, Fort Knox, Kentucky. These data begin to demonstrate the actual quantitative effects of communications degradation (speech intelligibility in this case) on performance of combat tasks and to quantify the significance thereof. Examples of the performance measures used include number of targets successfully acquired, engaged, and killed, and time taken to navigate a tank from one location to another. Garinther and Anderson (1996) have summarized these and other related data. Their depiction is presented in Figure 2.

Given this evidence of performance degradation resulting from lessened speech intelligibility, Garinther and others have worked toward improvement of the helmet and intercom systems used in mounted vehicles. One result of this effort is the Vehicular Intercommunication System (VIS) (Garinther and Anderson, 1996). The VIS, fielding of which began in 1996, is equipped with an active noise reduction (ANR) capability to enhance speech intelligibility. Based on data as shown in Figure 2, along with other data, Garinther and Anderson (1996, page 35) state that: "...computations show that successfully accomplished missions would increase by 25 percent [when using the VIS with ANR] for complex missions similar to those conducted in the ARL [Army Research Laboratory] studies." They also briefly describe ongoing efforts to further improve speech intelligibility by improving the speech signal-to-noise ratio entering at the microphone.

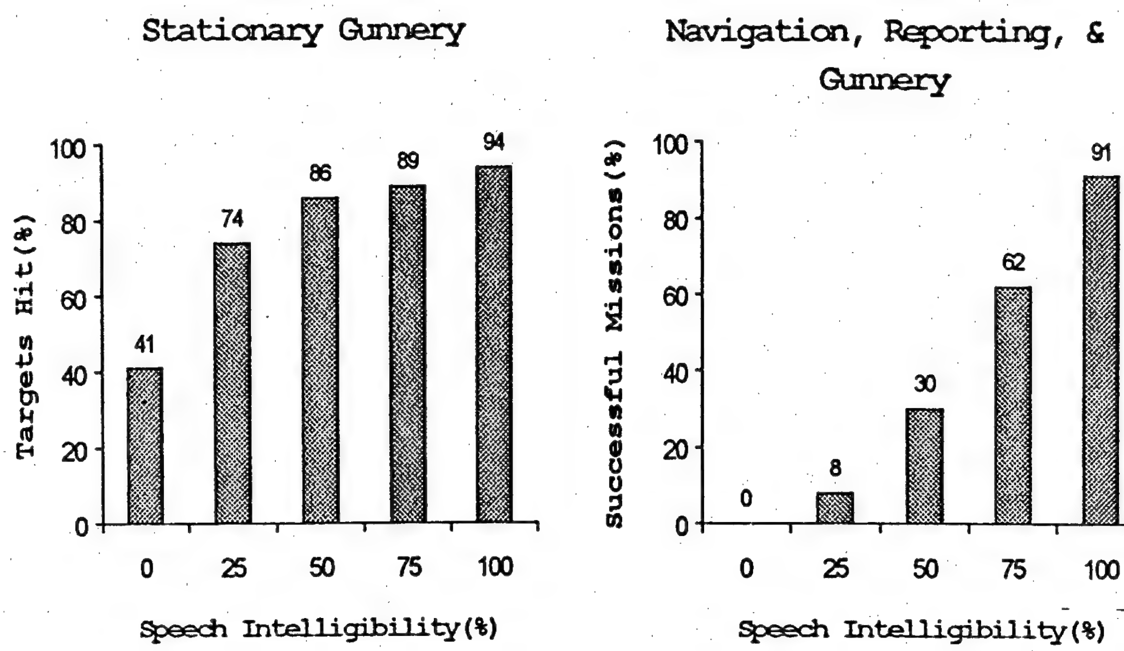

Figure 2. Performance of Armor crews for simple and complex scenarios as a function of speech intelligibility. (Taken from Garinther and Anderson, 1996, page 35.)

Requirements for Research on Tactical Skills in Dealing with Communications Realities

Abbreviated versions of our research goals were provided in the Research Background section. These are repeated here to reestablish the stage for describing research requirements:

1. Determine how to minimize adverse signal degradation effects on battle outcomes;

2. Determine how to optimize interdependent signal and warfighter tasks and task relationships; and

3. Identify the necessary training requirements and best training strategies.

With regard to the training world, these goals can be restated as:

1. Determine <u>what</u> can be done by soldiers to minimize adverse signal effects; these then become <u>training goals</u>. When the training goals are translated into task statements of <u>how</u> the soldiers are to accomplish them, these statements constitute <u>training objectives</u>;

2. Further define and refine the training objectives with respect to signal and warfighter task responsibilities and interdependencies; and

3. Identify the knowledge, skills, and attitudes required to achieve the training objectives; and the best strategies for acquiring these.

Areas of research needed to achieve these goals and to be discussed in this section include: (1) impacts of communications capability on battle processes and outcomes; (2) identifying training requirements; (3) training research questions, topics, and concerns; and (4) such other areas as changes in soldier functions, duties, and organization; and tools to aid digital battlefield performance. A recap of work within the context of the Close Combat Tactical Trainer (CCTT) will also be presented. The CCTT effort was an initial attempt to address research categories (2) and (3); this within the context of mounted maneuver operations at the lower echelons.

Impacts of Communications Capability on Battle Processes and Outcomes

A fundamental area, where findings would provide underpinnings and definition for development of applied solutions, is that of identifying cause and affect/effect relationships between changes in communications capability and subsequent changes in battle performance and outcomes. If changes in communications capability can be demonstrated to explicitly influence combat then addressing the enhancement or problem causing the change, for better or worse, becomes a worthy investment. The greater or more critical the impact is shown to be, the more worthy the investment becomes. Demonstrating the combat cost of signal degradation on battle processes and outcomes, and showing that these degradation effects can be avoided or ameliorated by soldier actions, would provide support for addressing our central concern here: the need for tactical training with respect to realistic communications. These same data could also support other concerns related to communications capabilities. Examples of such concerns include advances in technology; new or enhanced communications equipment and systems; and the other research areas, besides training, to be discussed here: changes in soldier functions, duties, and organizations; and supporting tools such as job performance aids.

Establishing the nature and extent of signal degradation effects on battle processes and outcomes will not be an easy task, however. Problems include lack of data on hand and lack of opportunities to obtain data. As discussed in the section on Communications Considerations, realistic changes in signal quality are usually not included - or permitted, or measured, or assessed - in live, virtual, or constructive simulations, no matter what the purposes of these simulations may be. In some problem analyses where signal realism has been incorporated, the

efforts have been criticized as being "unrealistic and incomplete" simulations of the signal operations themselves, and likewise the representations of their reality characteristics and effects (MAJ R. Christensen, personal communications, February 1993 - March 1994). In short, currently available information is either questionable or largely subjective and anecdotal. Means to systematically obtain valid and quantitative data are not immediately at hand. The ability to obtain systematic data through live, virtual, or constructive simulations could, however, be developed or may otherwise become available in the future. Possibilities for gaining data through these types of simulation will be discussed next.

With regard to live simulations, our first class of simulations, a word of caution is in order. Obtaining definitive information down to a detailed level in a field setting will be difficult; even though observations and other data from live simulations often provide insights that are very valuable and could not otherwise be seen as clearly. A review of Lickteig (1996) can provide useful information for live simulation research endeavors with regard to field experimentation difficulties, reasonable expectations, and approaches toward realizing these expectations.

The ACCES, described in the Research Background section, could provide one means for incorporating consideration of signal quality variations into live simulations. Here, the ACCES tools for collecting data on battle events, dynamics, and staff processes could be expanded to include: descriptions of variations in signal capability levels; causative factors; and the decisions and battle staff actions affected, nature of the affects, and reactions.

No virtual simulations - the second class of simulations - are currently in use which simulate any aspect of realistic signal degradation. (Jamming is an occasional exception, but only in a few simulations.) This situation is changing, however, in that the upcoming CCTT, a virtual simulation, will simulate some aspects of signal realism (although not that of jamming). Fielding of these limited CCTT capabilities will begin in 1998. It is hoped that the CCTT, and perhaps other simulations under development, will afford research opportunities in the future. Examples of "other simulations under development" include Warfighter Simulation (WARSIM) 2000 and efforts to add signal play to Distributed Interactive Simulation (DIS). The documented WARSIM 2000 communications requirements include some aspects of signal realism. The U.S. Army Signal Center is currently initiating efforts to meet these requirements as a part of this development effort (MAJ S. L. Merchant, personal communication, 30 April 1997).

The third class of simulation alternatives is constructive simulation. Analytical computer language system simulations, a form of constructive simulation, might well be the most immediate

means for analyzing and assessing the impact problem. It could also be a cost-effective path towards information which would richly complement data obtained from live and virtual simulations. A given, whatever the form of simulation, is to assure that its operations and variables are constructed such that reasonably valid data can be produced. Something like Obermayer's Command and Control Analysis Model (see Research Background section for discussion) might be developed which describes interactions between C1, C2, C3, and C4, and changes in total system performance when their tactical communications behaviors and skill levels are changed. If the Obermayer approach of working with an actual situation is attempted, then it would probably be best to start with a simple case. Such a case might be a small unit (e.g., platoon), performing a relatively simple mission in a limited scenario. If the computer language system simulation approach proves fruitful then a training benefit might also evolve. An example of this is Janus, also called JANUS. Janus began life as a system computer model, a constructive simulation, and has since been developed into a training medium. It is now used widely for battle staff training. For descriptions of Janus training capabilities see Campbell and Skilling, 1995; Elliott, Sanders, and Quinkert, 1996, pages 27-28; and U.S. Army Armor School, 1995.

It has also been suggested (P. Gillis, personal communication, 29 April 1997) that consideration be given to developing constructive simulations of cognitive C1 and C2 decision making loops for selected battlefield operations. Here, the impact of information (e.g., items related to METT-T and accompanying situational awareness) on decisions and, hence, on combat processes and outcomes would be modeled. This suggestion is akin to Obermayer's approach (Obermayer, 1975) but with emphasis on modeling the cognitive processes that result in the operational process flows modeled by Obermayer. Variables in this case would include information content and timeliness that would, in turn, have been determined by the variables of communications realism. Gillis suggested a goal for such a model(s) would be to produce quantitative impact data, much as did Obermayer's (1975) Command and Control Analysis Model, and Garinther and Anderson's (1996) empirical research on Armor crew performance.

One constructive simulation has been developed, and now being retired, that is directly relevant to our impacts issue. It has been used to evaluate such C3 and C4 characteristics as message load capacity, queue lengths, transmittal times, error rates, etc. These have been computed for specific, but static, combinations of situation, terrain, facilities, operational equipment, and communications network architectures as then existed or were under consideration as alternatives. This simulation has been called the communications Network Assessment Model, or NAM (personal communications, MAJ R. Christensen, Feb 93 - Mar 94; MAJ P. Minor, Dec 1992 - Sep 1993). The possibility of using NAM to create realistic communications conditions for

the Corps Battle Simulation (CBS) was investigated as a potential means of determining impacts of communications capability on battle processes and outcomes (our research issue here). (CBS is the current constructive simulation used for, among other things, corps and division command and battle staff training. It will be replaced by WARSIM 2000.) The NAM, however, had limitations that made satisfactory achievement of this objective difficult. The U.S. Army Signal Center is currently beginning efforts to replace the NAM with an updated, expanded, and dynamic communications simulation capability. One use planned for this new simulation is that of addressing impact assessment issues (MAJ S. L. Merchant, personal communication, 30 April 1997; U.S. Army Signal Center and Fort Gordon, 1997).

Efforts by the U.S. Army to examine the potential efficacy of the digital battlefield warfighting concept have used a combination of live, virtual, and constructive simulations in some AWEs. Despite the foregoing cautions (e.g., Lickteig, 1996), these have yielded valuable insights into training needs and other impacts on battle processes and outcomes (see earlier discussion of logistics impacts). While the identified training needs focused on operations and equipment procedures, rather than training needs related to signal degradation variations, these insights comprise an initial step towards such research. Among the digital training needs identified by the Focus Dispatch AWE (using all three forms of simulation in training and both live and virtual in the experiment itself) (Parry, et al., 1996, pages I-2 and 6-23) were:

1. Hardware training; "switchology."

2. Interconnectivity: command, control, and communications; and tactics, techniques, and procedures training at platoon and company.

3. Integrated, combined arms, force-on-force training using constructive and virtual simulations.

4. Live field training.

Identifying Training Requirements

Research to identify and assess signal degradation effects on battlefield outcomes as needed to begin identifying training goals and objectives was discussed above. Some procedures for specifying these training requirements will be described here. Later, an initial effort in this direction for the CCTT will be outlined. It should be noted that, while this report addresses the need for warfighter skills in avoiding and dealing with tactical signal degradation effects, others are also beginning to focus attention on the general concern of digital battlefield training. As noted above, Focus Dispatch AWE (Parry, et al., 1996) brought attention to the need for at least digital operations training. Another effort has been initiated where the

concern is not so much about digital operations training requirements as: "What are the training requirements for back-up modes of operation when automated systems are damaged or compromised?" (Department of the Army, 1996).

Procedures for Identifying Training Requirements. Three classes of simulation were discussed above as possible means for gaining information on requirements of several types (e.g., doctrine, materiel, training). What is also true, however, is that, while such research is needed and would be of great value in identifying, among other things, training needs, a considerable amount of progress can be made in its absence. This latter statement is true, however, only if these two assertions are accepted *a priori*: signal degradation can have negative effects and soldiers can minimize these effects.

If signal impacts research is performed and/or the two assertions are accepted then there are procedures that can be used to begin identifying the nature of tactical communications training needs and strategies for meeting them. For example, interviews, questionnaires, workshops, and various forms of discussion groups involving subject matter experts (SMEs) can provide useful information. Necessary complements to these tools are front end analyses (FEAs) as performed by training developers, combat developers, and other persons (e.g., human factors specialists) concerned with issues involving people in the accomplishment of missions. References covering both FEAs and subsequent development analyses include Meister's behavioral analysis compendium (1985) and TRADOC's (U.S. Army Training and Doctrine Command) Regulation 350-70 (1995) on instructional system development.

There is an important aspect of identifying tactical communications training needs that must be recognized when selecting and using information gathering tools - be they simulations, interaction with SMEs, or analysis procedures. This endeavor is not just one of identifying training needs or deficiencies for jobs that are completely defined; it is also one of expanding or changing job definitions and designs to include tactical communications degradation components. If it is accepted that soldiers can avoid or compensate for tactical signal degradation then job definitions need to be expanded to include the what of degradation avoidance and compensation. In short, the simulation, SME, and analysis techniques need to include job definition questions regarding what soldiers can and should try to accomplish - but either don't or often don't at the present time - as a prelude to defining the how-to-do tasks and detailing the training needs.

Detailing the Training Requirements. Once requirements have been identified then these must be further defined and detailed as needed for development; be it development of a training program, materiel system, or organizational structure. Here, iterative definitional steps will be presented in terms

appropriate for a training developer. These steps consist of sequentially defining:

1. Training goals;

2. Training objectives; and

3. Knowledge, skills, and *attitudes* (*KSAs*). (Note: the more usual meaning of the "A" in KSAs is "aptitudes." In this report, however, the "A" will always, and very intentionally, stand for "*attitudes*." An italicized *KSA* will be used henceforth as a reminder of this difference.)

The products of these three steps should relate to each other sequentially. Goals provide the basis for defining training objectives. Objectives, in turn, lead to definitions of *KSAs*. Each is the starting point for beginning the next level of detail in training needs specification. Definition of *KSAs* is a major analysis step completed by training developers before beginning the design of a training course.

The primary training audiences for these steps are warfighters and those signal personnel who support mission planning, preparation, and execution operations. Here, the second research goal, determining how to optimize interdependent signal and warfighter tasks and task relationships, comes to the forefront. As goals, training objectives, and *KSAs* are defined, an evolving part of this definition will be identification of the training audiences for whom they are intended. Major training audience groups would be: warfighters and/or signaleers training individually; and warfighters and signaleers training collectively.

For example, one *KSA* group might include *KSAs* pertaining to the entire training audience (e.g., all warfighters and signaleers). Other *KSA* groups might be specific to subsets of the overall training audience. For example, it may be that not all of the *KSAs* for an Armor platoon leader would be identical to those of, for example, a battalion commander; and some *KSAs* for a brigade battle staff fire support officer would not be the same as those for an Armor company first sergeant. In the CCTT effort, it was found that statements of training goals at a general level of definition were substantially correct for each echelon when echelon levels were not greatly separated. When moving to the levels of specificity appropriate for training objectives and *KSAs*, however, echelon and position differences became increasingly pronounced (Finley, 1997).

How training goals, objectives, and *KSAs* might be stated can be demonstrated by examining one each from those determined in the CCTT effort for a specific case of an Armor platoon (Finley, 1997). They were:

1. Goal: Have knowledgeable expectations regarding communications degradation.

2. Objective: Be able to develop a communications tactics course of action (COA) and contingency plans.

3. *KSAs*:

a. Knowledge: Know the factors and conditions affecting Single Channel, Ground/Air Radio System (SINCGARS) communications quality characteristics.

b. Skill: Be able to perform equipment operating procedures supporting the communications responsibilities of the tank crew member's own position; and backup procedures needed in the case of loss of equipment or another crew member.

c. *Attitude*: Recognize the importance of not informing the OPFOR unnecessarily and practice radio discipline accordingly.

Training Research Questions, Topics, and Concerns

Two primary training concerns for the military are skill acquisition and skill sustainment. From the military's applied perspective, principle questions with regard to both are: What for Whom?, When?, Where?, and How? (W4H). Answers to these W4H questions may not always be immediately obvious for all tactical communications degradation *KSAs*; research may be required.

Specific research questions and resulting solutions for each of the four W4H questions could be many. Here, some possible topics for these questions are suggested:

1. What for Whom: Training objectives and *KSAs* comprise the overall group of "whats." These "whats" are associated with training audience identities, the "whoms." A training audience could range from the entire Army to only those soldiers serving in one particular position in a special location. Examples of attributes defining the training audience for a *KSA* include: line or staff positions; individual or collective performance; branch function and occupational specialty. At least two research topics come immediately to mind: (1) Which tactical communications degradation *KSAs* or common parts of many *KSAs* constitute material for which standardized training components could be used and/or could constitute components of common core education and training (e.g., officer basic courses, advanced non-commissioned officer courses)? and (2) How can warfighter and signal soldiers be better educated and trained with regard to their task interdependencies as a part of individual instruction preceding collective training?

2. When: "When" can have at least three definitions of time. One of these is points in the progression of a military

career. Another is points in the sequence of training in a particular course or in a larger training program. When considering skill sustainment, a third "when" question is, "How frequently does training need to recur?" An indication of the importance of all three of these "when" questions, but especially the third one, is this observation on the Focus Dispatch AWE experience: "Digital skills are hard-won and highly perishable." (Parry et al., 1996, p. I-3)

3. <u>Where</u>: "Where" is mainly a resource and logistics question when there is a choice of locations and the training benefits appear to be equal. For example, if the same training device is available at two locations then the choice may be based on scheduling capabilities and distance. If, however, the benefits are not obviously equal, and cannot be made so, then it might be asked which location best meets which types of training needs. This is a "how" question where the answer will help determine which location, or "where."

4. <u>How</u>: "How" can refer to the means, or medium, and/or the pathway and circumstances of training. The term, "training strategy" more often refers to the latter. However, with more complex training media that can be tailored in various ways, such as some virtual simulations, "training strategy" may also describe the manner in which that particular medium is used. The examples of possible "hows" presented next will include both means and pathways, i.e., both media and strategies.

a. <u>Media, Means</u>: An enormous variety exists, many members of which can be used in combination with others (e.g., sequentially, simultaneously). Examples include: live, virtual, and/or constructive simulations; other training media such as textbooks or intelligent tutors; training environments (e.g., classroom, garrison, field); contexts (scenarios, types of terrain, weather, OPFOR capabilities); student handling (e.g., alone, in interactive groups); and feedback provided (e.g., real-time coaching, after action reviews (AARs), take-home packages).

b. <u>Strategies, Paths and Circumstances</u>: Training strategies can be characterized in many ways. Some of these are: (1) The means and pathway specified for progression from individual to collective tactical communication reality *KSAs*; (2) Integrating tactical communications skill acquisition into the acquisition of other collective skills so as to cause a minimum of disruption; (3) Skill sustainment schedules and procedures; and (4) Making choices regarding when and exactly how training media are to be used. One broad training strategy issue warranting research might be, "How can collective training best be organized to progress from crawl, to walk, to run skill levels with regard to the total set of collective training objectives, to include objectives related to avoidance of and compensation for degraded tactical communications?" A more limited strategy question within this larger one might be, "At what point(s) in mounted battle maneuver training should we play signal

degradation effects resulting from OPFOR action; and which OPFOR actions should we play?"

Research to find answers to questions such as the ones posed above will undoubtedly address skill acquisition first; but it will probably be necessary to investigate W4H questions regarding skill sustainment as well. One reason why some questions regarding both acquisition and sustainment training may be viewed as critical are the facts that they both impact on these concerns: (1) Training calendars are already overloaded with *KSAs* to be taught and trained on many topics other than signal degradation; and (2) Realistic signal degradation during a training exercise can reduce the time available or modify the situation needed to train these other *KSAs*. In short, although training tactical communications skills is important, it must be done in a manner that allows for efficient acquisition of the rest of the great many *KSAs* requiring education and training. Reasons for the criticality of these concerns are the matters of limited resource affordability and availability. Given such issues, information will be needed regarding exactly what the training requirements are, which available options meet these requirements, and what other options might be considered.

Close Combat Tactical Trainer (CCTT) As an Initial Training Research Step

The CCTT is the first training environment - be the environment live, virtual, or constructive - designed to systematically provide certain variations in electronic communications quality as would be experienced on an actual battlefield when conducting tactical maneuvers and engagements. Requirements for the CCTT are to provide the means to "...develop the synergism and practice skills across all the Battlefield Operating Systems (BOSs) of a battalion task force or cavalry squadron and their subordinate and supporting elements." (U.S. Army Armor Center and School, 1995, p. 1) The CCTT is under development and initial fielding is expected in 1998.

Finley (1997) initiated an exploration of this new training environment with respect to its communications realism aspects. This exploration addressed Armor and Mechanized Infantry platoons equipped with the conventional Single Channel, Ground/Air Radio System (SINCGARS). Conventional SINCGARS is limited to voice as found in M1A1, M2A1/2, and many other vehicles. Training with the SINCGARS model with Inter-Vehicular Information System (IVIS) (found in the later M1A2) and other SINCGARS models with data carrying capabilities, and company and battalion echelon training, will be explored in the future as CCTT simulation capabilities evolve to include these.

Training goals, objectives, and *KSAs* were identified for the conventional SINCGARS platoon. The goals were found to be:

1. Have knowledgeable expectations regarding communications degradation;

2. Plan, prepare, and execute according to these expectations;

3. React effectively to unexpected degradation; and

4. Proactively monitor and control communications in order to maintain both capability and availability, and to deny advantages to the OPFOR.

Of particular interest here is the finding that the broader statements and sequence of training goals, objectives, and *KSAs* appear to provide a relatively generic model. Perhaps this is because a broader, top down approach was taken in the analysis process, beginning with considerations of soldiers in positions ranging from tank commanders to battle staff members. The field of view was then narrowed and focused on the platoon. It was found that the broad descriptions of training requirements and strategies were generally applicable at the platoon level and could then be specified appropriately. It also appears that the model will be useful as a general structure for at least the company and battalion maneuver echelons as well. As might be expected, comparatively minimal requirements for platoon training in communications degradation realism were identified. This is as would be expected due to the nature of: what is done by the platoon; how the platoon members do it; the limited communications assets available to them; and the uses they make of these assets.

In addition, training strategies and implementation approaches were outlined. Training frequency, duration, and context considerations were also discussed. The recommended overall training strategy was that of simulation-based structured training using training support packages (TSPs) (Campbell, Campbell, Sanders, Flynn, & Myers, 1995) as have been previously created for Simulation Network (SIMNET) and Janus (e.g., BDM Federal, Inc., PRC Inc., Human Resources Research Organization, 1995a, 1995b).

<u>**Other Areas of Research**</u>

The first research requirement discussed, that of identifying and assessing signal degradation impacts on battle processes and outcomes, was presented primarily as a step towards identifying training requirements and addressing other training research issues. Information stemming from impacts research would also be useful in addressing at least two other areas of research. These are: (1) Changes in soldier functions, duties, and organization; and (2) Tools to aid digital battlefield performance. Initial concepts and investigations in these two areas are presented next.

Changes in soldier functions, duties, and organization. TRADOC Pamphlet 525-5 (U.S. Army, 1994) sets the stage for Force XXI information age operations in dynamic strategic environments. In discussing battle command, anticipated changes are described:

> Advances in information management and distribution will facilitate the horizontal integration of battlefield functions and aid commanders in tailoring forces and arranging them on land. New communications systems allow nonhierarchical dissemination of intelligence, targeting, and other data at all levels. This new way of managing forces will alter, if not replace, traditional, hierarchical command structures with new, internetted designs. (page 2-8)

It has been forecast that the technology changes of the information age will affect not only battle commanders but also those they command. Changes may be needed in: what soldiers do and how they do it; their functional breakouts (i.e., a staff breakout different from such traditional components as operations, intelligence, artillery, and combat service support may be more effective); and their organizational structures and alignments. Described next are AWE observations and recent research efforts bearing on these concerns.

Observations from the Focus Dispatch AWE, which examined digitized battalion task force maneuvers (Parry et al., 1996), included:

1. "Staff. There is no evidence that staff organization should change; however, the role of the Signal Officer will expand to include network management tasks." "Signal Additions. We will need to expand the number of signal soldiers at battalion and brigade level due to increased requirements for network construction and management." (p. I-7, b. and c.; p. 6-25, [b] and [c])

2. "The degree of capability supplied by digitization to the FD [Focus Dispatch] unit did not indicate a need to alter the size of the Bn/TF [Battalion/Task Force] or the TF staff. What was clear, however, was the impact of the systems on the role and responsibilities of the signal officer. When the design of the TFXXI Applique' and Tactical Internet is better developed, the Bn/TF signal element's role and composition must be determined." (p. 1-8, j.)

Researchers have begun to investigate these personnel function, task, and organization issues. Examples include:

1. Reviewing behavioral science literature on group processes (Beck and Pierce, 1996);

2. Performing analyses to develop alternative concepts for staffing a new battle command vehicle (Pierce, Rappold, and Flanagan, 1995); and

3. Developing transitional and new organizational structures for command and control at the battalion level through modeling, simulation observations, and SME interviews (Sonnenwald and Pierce, 1996).

Other researchers addressing this area are taking a complementary approach. They are focusing on the development of procedures for detailed modeling and analysis of command and control staff processes from behavioral standpoints. They are especially concerned that changes in workload distribution and other changes may be occurring due to the introduction of new computer and communication technologies into command and control centers. These researchers consider "Finding the right tactics, organization, soldier machine interface, manpower, personnel, and training needed to maximize the utility of these developments [to be] a major challenge." (Ensing and Knapp, 1995) Thus far, they have initiated efforts related to the Army's new Command and Control Vehicle, currently under development, and the design of command and control centers for ballistic missile defense (Ensing, Knapp, & Johnson, 1996; Knapp, Ensing, & Daniel, 1996).

<u>**Tools to Aid Digital Battlefield Performance.**</u> Tools to aid job performance include at least planning tools, decision aids, and job performance aids (JPAs). Among the findings from Focus Dispatch AWE were observations regarding what job tools were found to be useful and additional ones that should be developed (Parry et al., 1996). These tools ranged from procedural checklists to sophisticated simulation capabilities that could be used for mission planning and rehearsal purposes. The observations were:

1. "The most significant change caused by digitization is in the management of the communications network. Because digital tasks must be performed precisely, procedures should be reduced to checklists ... Digitized units should develop procedures to indicate who will have direct links to artillery/mortars and when ... [communications and digital tasks] should be planned and rehearsed before the execution of missions." (p. 6-39, 6-40)

2. "A digital course of action (COA) development tool, one with embedded rehearsal capability that integrates all BOS [battlefield operating systems] enhances execution. Using Janus as a rehearsal tool (during Janus 3) rather than the traditional sand table, the experimental force demonstrated a marked increase in the level of its detail and learning, and its understanding of mission, commander's intent, and factors influencing the battle. The foremost result was the ability of the unit to synchronize the battlefield. We must get a high resolution digital COA and rehearsal tool into the hands of our units as soon as possible. This would allow the unit to perform an informed intelligence preparation of the battlefield and, using line of sight features, examine proposed locations, routes, and schemes of maneuver. This will require providing accurate weapon systems and terrain

databases to the units for their training and contingency areas." (p. 1-6, e.)

Developing truly effective and efficient job tools is often not the easy task that it appears to be on the surface. Developing tools for jobs affected by electronic communications - where the quality of communications can sometimes vary as a function of more than one variable - may, in some cases, be a challenging task.

Summary

This report describes requirements for behavioral research concerning signal realities - i.e., variations in electronic communications and automation capabilities - that occur as a part of tactical operations. The focus is on <u>tactical</u> signal knowledge and skills needed by both warfighters and signal soldiers during operations on a dynamic battlefield.

The realities of the battlefield are such that successful transmission and reception of electronic communications - not to mention the completeness and validity thereof - are never certainties. This is especially true during dynamic tactical engagements. Common limiting factors under these conditions include distance, terrain obstructions to LOS, electronic interference, and hostile actions by the OPFOR.

Warfighters are increasingly becoming GPUs of signal equipment, and being assigned critical and expanding roles in using this equipment. Warfighters are soldiers, however, whose training and direct responsibilities are in combat, not signal (e.g., infantry, artillery). Signal soldiers, who are the ones trained in electronic communications and automation technologies, support warfighters to the extent feasible. However, the current paucity of signal personnel at lower echelons (especially at battalion and below) means that immediate and direct support is often not possible. However, even if more signal soldiers were to become available at these echelons, placement of them in combat vehicles along with the warfighters is generally not an option due to vehicle size, nor appropriate due to the associated warfighting skill requirements and responsibilities.

Despite these changing conditions and roles for warfighters, their standard training environment, at present, remains one of perfect, i.e., unrealistic, communications insofar as possible. Current training for warfighters does not intentionally or systematically address how to avoid degradation in communication capabilities or how to handle unavoidable degradation. This situation will change to some extent with the introduction of CCTT and WARSIM 2000 simulations for training.

Two assertions made in this report are that: (1) Tactical signal degradation <u>can</u> have negative effects on battlefield processes and outcomes; and (2) Warfighter GPU soldiers, working

with signal soldiers to the fullest extent possible, can minimize these effects if appropriately trained. Evidence suggesting these assertions may be true is presented and discussed.

The purpose of the proposed research is to increase the probability that potential gains from digitizing the battlefield will be realized. The research goals addressed here are ones seeking further and more detailed evidence to support or deny the assertions, and to guide development of training and other solutions. Solutions sought are one which will enhance the ability of soldiers to maintain tactical communications capability and quality. Research to provide evidence and necessary information is described in several areas. These areas are: specifying the impacts of communications capability on battle processes and outcomes; identifying training requirements; answering related training research questions and concerns; exploring possible changes in soldier functions, duties, and organization; and developing tools to aid digital battlefield performance. A completed effort on the CCTT is described as an initial research step in the training areas.

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List of Acronyms

AARs	After Action Reviews
ACCES	Army Command and Control Evaluation System
ANR	Active Noise Reduction
AWE	Advanced Warfighting Experiment
C1	Command
C2	Control
C3	Communications
C4	Computers, Automation
CBS	Corps Battle Simulation
CCTT	Close Combat Tactical Trainer
COA	Course of Action
CS	Combat Support
CSS	Combat Service Support
CTCP	Combat Trains Command Post
DA	Department of the Army
DIS	Distributed Interactive Simulation
FEA	Front End Analysis
FM	Field Manual
GPSS	General Purpose Systems Simulator language
GPU	General Purpose User
IMA	Information Mission Area
IVIS	Inter-Vehicular Information System
JPA	Job Performance Aid
KSAs	Knowledge, Skills, and Attitudes
LOS	Line-of-Sight
METT-T	Mission, Enemy, Terrain, Troops, and Time Available

NAM	Network Assessment Model
OPFOR	Opposing Force
SIMNET	Simulation Network
SINCGARS	Single Channel, Ground/Air Radio System
STRICOM	U.S. Army Simulation, Training, and Instrumentation Command
SMEs	Subject Matter Experts
TSPs	Training Support Packages
USA	U.S. Army
VIS	Vehicular Intercommunication System
WARSIM 2000	Warfighter Simulation 2000